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ABSTRACT

The National Academy of Sciences at its 112th Annual Meeting on April 21, 1975, paid homage to the comparatively young National Science Foundation (NSF), in celebration of its 25th birthday. The planning that went into the symposium will become clear to the reader of these four papers, which are quite different in style and content but united by their central concern with the past and future of NSF. Detlev W. Bronk draws on the rich lode of his memory as he describes the Foundation's origins and aspirations. William A. Fowler describes by examples how the Foundation's investment in research has changed our understanding of Planet Earth, the gene, and the universe and is aiding the transfer of knowledge to an attack on environmental and social problems. Joseph B. Platt assays NSF's education programs in the light of recommendations in Dr. Vannevar Bush's report. Finally , H. Guyford Stever reflects on the directions that the Foundation may take in the years that lie ahead, during a time of growing awareness among scientists that they are also citizens and that their research often affects and is affected by individual and social values. (LS)

The First Twenty-Five Years of the NATIONAL SCIENCE FOUNDATION

A Symposium of the

NATIONAL ACADEMY OF SCIENCES

April 21, 1975

Foreword

The National Academy of Sciences at its 112th Annual Meeting on April 21, 1975, paid homage to the comparatively young National Science Foundation, in celebration of its twenty-fifth birthday. The four papers presented here were read to a large and appreciative audience in a symposium presided over by Norman Hackerman, Chairman of the National Science Board, and his immediate predecessor in that position, H.E. Carter.

The planning that went into the symposium will become clear to the reader of these four papers, which are quite different in style and content but united by their central concern with the past and future of the National Science Foundation. Detlev W. Bronk draws on the rich lode of his memory as he describes the Foundation's origins and aspirations. William A. Fowler shows by striking examples how the Foundation's investment in research has changed our understanding of Planet Earth, the gene, and the universe and is aiding the transfer of knowledge to an attack on environmental and social problems. Joseph B. Platt assays NSF's education programs in the light of recommendations in Dr. Vannevar Bush's report and thoughtfully analyzes the new educational challenges that the agency now faces. Finally, H. Guyford Stever reflects on the directions that the Foundation may take in the years that lie ahead, during a time of growing awareness among scientists that they are also citizens and that their research often affects and is affected by individual and social values.

The Board extends its appreciation to Philip Handler, President, National Academy of Sciences, and its Members for providing a special forum for this opportunity to reflect on our heritage as we mold our future.

Norman Hackerman
Chairman,
National Science Board

H.E. Carter
Chairman, National Science Board Committee on the 25th Anniversary

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A Brief History of the National Science Foundation

In November 1944, as Allied victories raised hopes for an end of World War II, President Roosevelt asked Vannevar Bush to recommend ways to use the lessons of wartime science in the days of peace ahead. Dr. Bush's famous report, *Science—The Endless Frontier*, released to the public by President Truman in July 1945, recommended the establishment of a new Federal agency to support basic scientific research and develop scientific talent. A bill based on the Bush report, introduced by Senator Warren G. Magnuson, and a rather different measure sponsored by Senator Harley M. Kilgore, began a five-year debate involving the proper balance of scientific freedom and public responsibility before an acceptable compromise was achieved in the National Science Foundation Act of May 10, 1950.

While the Congress debated, other Federal science agencies came into being. From one of these President Truman selected NSF's first Director, Alan T. Waterman, whose record as Chief Scientist in the Office of Naval Research had won acclaim in the scientific community. Later the National Science Board, the policy-making body of the Foundation, held its first session in the Cabinet Room of the White House on December 12, 1950. Dr. Waterman continued as Director until 1963. He chose his associates carefully and worked harmoniously with the Board during the formative years. A quarter-century after its creation, the Foundation still reflects the emphasis on excellence and high quality that the first Director, the first Board, and the first staff members gave to the development of policies and programs.

NSF's budget grew slowly in the early years. Most of the funds supported basic research projects in the natural sciences and fellowships for graduate students. But important new programs—institutes for high school and college teachers, improvement of courses for elementary and secondary schools, the development of a national research center for radio astronomy, and cooperation with other nations in the Antarctic and elsewhere in the International Geophysical Year—were all undertaken before the Soviets launched their first Sputnik in October 1957. That event soon brought substantial increases in the Foundation's funds for research and education in the sciences. Other noteworthy early activities included the inauguration of economic and manpower studies of science resources, the creation of science information services, the beginning of research support in the social sciences, and the issuance of occasional policy statements by the Board, notably one on loyalty and security considerations in unclassified research.

In its first decade the Foundation concentrated on the advance of science by supporting individual researchers and students. In the 1960's it ventured into a new frontier for a Federal agency—investment in institutions of higher learning in order to strengthen the academic base for the future. Under the conscientious guidance of Leland J. Haworth, who succeeded Dr. Waterman as Director, the Foundation's institutional and traineeship programs sought to increase the number of excellent centers of research and graduate education throughout the Nation, while other new programs bolstered undergraduate science. In these years, too, NSF fostered the creation and growth of large national research facilities and increased its cooperative arrangements with other countries.

New directions for NSF came with the passage of the Daddario-Kennedy Bill in 1968. This revision of the Foundation's charter enabled the agency to respond to the rising anxiety about social and environmental deterioration by authorizing the support of "applied scientific research relevant to national problems involving the public interest." The Foundation's third Director, William D. McElroy, welcomed this opportunity and vigorously championed research and education that would bring science more directly into service to society. H. Guyford Stever, the Director since 1972, has expanded NSF's relationships with the scientific and technological community as well as increasing NSF's involvement in international scientific efforts. Dr. Stever and the Board have, in addition to these other important endeavors, also continued to support strongly the Foundation's basic research as a national resource.

Introduction

Following are the four papers presented at a symposium at the National Academy of Sciences in recognition of the National Science Foundation's 25th anniversary. The symposium was held in the Academy's Hugh Dryden Auditorium on Monday, April 21, 1975. To the National Academy of Sciences and Dr. Philip Handler we offer our sincere appreciation and gratitude for the Academy's willingness to hold a special symposium to commemorate the first 25 years of the National Science Foundation during its Annual Meeting. The authors, titles, and order of presentation are listed below; the texts follow.

Detlev W. Bronk, President Emeritus, The Rockefeller University: *Origins, Hopes, and Aspirations.* Served on the National Science Board from November 1950 to May 1958 and from July 1958 to May 1964. Served as Chairman from May 1963 to May 1964.

William A. Fowler, Institute Professor of Physics, California Institute of Technology: *A Foundation for Research.* Served on the National Science Board from June 1968 to May 1974.

Joseph B. Platt, President, Harvey Mudd College: *Science Education—Who, Why, and How Did It Work Out?* Served as Member, National Science Foundation Divisional Committee for Graduate Education from January to July 1965. Served as Member, Vice Chairman, and Chairman of National Science Foundation Advisory Committee for Science Education from 1965 to 1975.

H. Guyford Stever, Director, National Science Foundation: *Whither NSF—The Higher Derivatives.* Served on the National Science Board from May 1970 to present. Appointed Director of the National Science Foundation in February 1972.

Dr. Detlev W. Bronk
President-Emeritus, The Rockefeller University

for the
National Academy of Sciences Symposium
on the Occasion of the 25th Anniversary
of the National Science Foundation
April 21, 1975

National Science Foundation— Origins, Hopes, and Aspirations

The origins of the National Science Foundation were in the visions of many scientists and Federal statesmen during a decade of profound changes in the institutions of American science. But the concepts that underlie the Foundation reach back into the beginnings of our scientific endeavor in Colonial America; Franklin and Jefferson, scientists and statesmen, paved the way for close association between Government and science.

Because anniversaries such as this are occasions for recalling people and for the celebration of their achievements, I have chosen to tell my fragment of the history of the National Science Foundation as recollections of those in whose dreams the origins of our Foundation are rooted, what were their hopes and aspirations.

It is appropriate to begin with the hopes of that one who did more than any other to bring the Foundation into being. A year before it was created, Vannevar Bush, our patron saint, wrote:

When the wheels of Congress finally revolve, we will have a National Science Foundation. As it proceeds, if it is wisely supported, it can ensure federal support of university research; it can provide fellowships for the brilliant; it can go a long way toward providing that equality of higher educational opportunity which we need to superimpose upon our educational system as a whole, in order to adapt it for our true purposes in this world of threats. It can formulate and support a sound governmental attitude toward science, and scientific education, in these days in which the burden of both has increased to the point where it can be carried only at federal expense. It can guard against the heavy hand of bureaucracy and furnish a bulwark against political pressure on this vital aspect of our interests. It can further science, free science pursuing its independent

way to unravel the mysteries of existence, carried on by free men whose guide is truth and whose faith is that it is good to know. As it does so, it can aid much to protect us all from the vicissitudes of nature and of selfish man.

The Legislative Process

The first person I heard use the term "National Science Foundation" in Federal legislation was Herbert Schimmel, a young physicist from the University of Pennsylvania. The role that he and his friend, Senator Harley Kilgore, played in our early history is now largely forgotten. But their persistent efforts to create an agency of Government to finance science and technology stimulated much discussion and legislative action that had considerable influence in the origins of our Foundation.

Like many others who received their doctorate but no university appointment during the years of depression, Schimmel turned to Government for employment of his knowledge of science and its social uses. His experiences in depression-affected universities encouraged his hopes for Government-supported science.

During an investigation of war production for the Senate Small Business Committee, Schimmel decided that the Government should equip itself with means to provide for its technological needs and not rely completely on industries that had not been designed to care for a major war emergency. Consequently, he began to formulate plans for an office of technological mobilization that would encourage the practical application of scientific discoveries.

He suggested those plans to Senator Kilgore, whom he had met while the Senator was investigating the rubber program as a member of the National Defense Investigating Committee, better known as the Truman Committee. Kilgore was favorable to Schimmel's suggestion and with the approval of Senators Truman and Pepper sponsored the first Technological Mobilization Bill in August 1942. The bill evoked little public interest and was opposed by leading members of the National Academy of Sciences. It expired with the 77th Congress.

In the 78th Congress of 1943, Senator Kilgore, with the assistance of Schimmel, introduced the Scientific and Technological Bill. It was somewhat less antagonistic to the role of industry than was its predecessor, and its broader objectives provided support of scientific and technological education and international scientific cooperation. Scientific leaders opposed what they considered dictatorial powers of the proposed agency.

Science—The Endless Frontier

Meanwhile, Bush had been thinking about the future of the Office of Scientific Research and Development and what had therein been learned that could be helpful in planning the future role of Government in the furtherance of science. His colleagues drafted a letter for President Roosevelt in which he asked Bush four major questions: What can be done to organize a program for continuing the war of science against disease? What can the Government do now and in the future to aid research activities by public and private organizations? Can an effective program be proposed for discovering and developing scientific talent in American youth so that the future of scientific research in this country may be assured on a level comparable to what has been done during the war? What can be done, consistent with military security, to make known to the world as soon as possible the contributions to scientific knowledge which have been made during our war effort? The letter ended: "New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war, we can create a fuller and more fruitful employment and a fuller and more fruitful life."

With characteristic respect for the wisdom of others, Bush promptly appointed four committees to consider the four questions and then counsel him on his advisory replies. They were aided by two score scientists who worked steadily on the four committees throughout the early months of 1945.

From their reports evolved *Science—The Endless Frontier* (report requested by Roosevelt). By the time that was completed in July, President Roosevelt, the friend who had given Bush unwavering support during five years, was dead. And so the historic report went to President Truman. "Although this report which I submit herewith," said Bush, "is my own, the facts, conclusions, and recommendations are based on the findings of the committees which have studied the questions."

Bush proposed the creation of a National Research Foundation. Its purposes were to "develop and promote a national policy for scientific research and scientific education, . . . support basic research in non-profit organizations, . . . develop scientific talent in American youth by means of scholarships and fellowships, and . . . by contract and otherwise support long-range research on military matters."

Even in those days that were still colored by New Deal liberal philosophies, it was bold to propose that the Government provide millions of dollars for adventurous research and the education of a

select few. Still bolder was the unprecedented plan to entrust the expenditure of those millions to a board of private citizens.

Bush himself predicted: "To persuade the Congress of these pragmatically inclined United States to establish a strong organization to support fundamental research would seem to be one of the minor miracles." And he was well aware that his close friend Frank Jewett "was sure we were inviting federal control of the colleges and universities and of industry itself . . . [and] that the independence that has made this country vigorous was endangered." The National Association of Manufacturers had published a pamphlet entitled, "Shall Research be Socialized?" But it was a time of high hopes, faith in new institutions with which to rebuild a war-torn world, and confidence that science could help create a better society of men.

And so the proposals formulated by Bush were embodied in a bill that was, with skillful timing, introduced in the Senate by Senator Warren Magnuson on the very day that *Science—The Endless Frontier* was released by the White House. It authorized the creation of a National Research Foundation. The structure of the Foundation resembled in many ways the organization of private agencies such as The Rockefeller Foundation and the Carnegie Corporation. It was strongly supported by the presidents of many leading universities, eminent scientists, and prominent industrialists.

Kilgore had hoped to collaborate in the preparation of the bill, but his proposals for management of a foundation and his policies regarding patent rights were unacceptable to Bush. And so Kilgore, with the assistance of Schimmel, in the following week introduced his bill that authorized the creation of a National Science Foundation. This bill was favored by President Truman.

Truman Veto

There was potential danger for both bills during two years of lobbying and acrimonious debate. I recall two relevant articles that appeared in *Fortune* during the forties: "Still Missing: A Technical Agency for Lost Ideas" and "The Great Science Debate: The atom touched off a great debate on a national science policy." But some form of Federal support for scientific research and education was widely favored. Ultimately a compromise bill was drafted that was endorsed by the Committee Supporting the Bush Report. It was passed by both Houses in the summer of 1947. Within two weeks it was vetoed by the President.

The pocket veto did not require that the President state his reasons, but he did. His respect for science was clear in his published statement that began:

I take this action with deep regret. I have urged the Congress to enact legislation to establish a National Science Foundation. Our national security and welfare require that we give direct support to basic scientific research and take steps to increase the number of trained scientists.

However, this bill contains provisions . . . that imply a distinct lack of faith in democratic processes.

The powers of the proposed Foundation would be vested in 24 members appointed by the President. . . .

The Foundation would have a chief executive officer, known as the Director. He would be appointed by the 9-member Executive Committee of the Board unless the 24-member body chose itself to appoint him. The powers and duties of the Director would be prescribed by the Executive Committee and exercised under its supervision.

The President would be deprived of effective means for discharging his constitutional responsibility because full authority and responsibility would be placed in 24 part-time officers whom the President could not effectively hold responsible for proper administration. Neither could the Director be held responsible by the President, for he would be the appointee of the Foundation.

Here it is appropriate to speak of the relations between Truman and Bush as I knew them. They had high regard for each other and were alike in many respects—forthright, sincere, courageous, and sometimes obstinate in defense of their beliefs. Truman made tough decisions that enhanced Bush's "faith that our sometimes absurd political processes can and do produce leaders of stature."

Finally, there was compromise between those two strong-willed but reasonable men. They agreed on a bill which provided for a Board of 24 appointed by the President, a Director appointed by the President after consultation with the Board; the Director was to be responsible to the Board. And so, five years after the publication of *Science—The Endless Frontier*, Truman signed S. 247 on May 10, 1950.

It was generally assumed that Bush would be Chairman of the Board of the Foundation whose creation he had fostered. In *Pieces of the Action*, he has told why he was not. At an Armed Services Day dinner at the Mayflower Hotel, Bush sat next to Truman.

The subject of the science board came up, and I said, "Mr. President, I wish you would leave me off that board. I know my name is on the list, but I wish you would leave me off." He said, "Why?" and I said, "Well, I have been running about everything scientific during the war, and somewhat since, and I think

people are getting tired of seeing this guy Bush run things around here. I think this outfit would do better if it had some new leadership. If you put me on the board, they will elect me chairman, and I do not think that the body of scientists are going to like this continuation of one man in the top post. So I think you would do better to let somebody else do it." Well, after a bit more talk, he agreed to leave me off the board. Then he said, "Well, Van, you are not looking for a job, are you?" And I said, "No, Mr. President, I am not looking for a job." He said, "You cannot say I went looking for this job that I am in." And I said, "No, Mr. President, not the first time," which tickled him quite a bit. He poked me in the ribs and said, "Van, you should be a politician. You have some of the instincts." I said, "Mr. President, what the hell do you think I have been doing around this town for five or six years?"

Such was the relationship between those two who guided the creation and shaped the structure of the Foundation: very pleasant, very informal, and on a basis they both greatly enjoyed.

The role of Bush in the Foundation was thus ended; his historic mission had been accomplished. But he lived to see 94 Members serve during 24 years on the Board to which the Director was responsible, as he had urged. And Truman continued in office long enough to appoint the first Director as he had insisted should be the prerogative of the President. Six years later when I last saw him at a Brandeis Commencement, he spoke of Alan Waterman's remarkable achievements as the first Director of a Foundation many thought could not succeed. Then with a grin he boasted, "I appointed him as I knew damn well I should."

The Board and Waterman Appointed

John Steelman, Assistant to the President, spent much time selecting the 24 Members of the first Board so as to have diversity of political, geographical, religious, and racial representation. Those the President finally nominated included three presidents of large corporations, two presidents of private foundations, seven presidents of universities, and four deans. There was some criticism, but most were satisfied because all the university presidents had been scientists and professors and 16 states were represented. Six weeks were required for Senate confirmation, but that was not surprising in the days of Joseph McCarthy.

The First Meeting of the Board was held on December 12, 1950. James Conant was elected Chairman of the Board. Then during the next two meetings there was much discussion about whom we should recommend to be appointed Director. Fortunately, our uninfluenced enthusiastic recommendation of Waterman satisfied Truman's requirement: "somebody who can get along with me."

At that time William Golden, a Special Consultant to the Director of the Bureau of the Budget, was reviewing the organization of the Government for promoting scientific activities. Soon after the first meeting of our Board, he sent to the President a memorandum: "Mobilizing Science for War; a Scientific Adviser to the President." Although the Golden proposal had been approved by many leading scientists, it aroused opposition among Members of the National Science Board at their second monthly meeting. In reporting this to the Bureau of the Budget, Conant told of the Board's concern that the appointment of a Science Adviser to the President would lower the status of the Foundation and reduce its appeal for congressional appropriations. There was further fear that their duty "to secure the national defense" would be impaired by the new Office of Science Adviser.

The Foundation's Mission

Golden promptly sent the following statement to all Members of the Board:

> It may be worth repeating that in accordance with the spirit of the Act, as well as the judgment of substantially all scientists with whom I have discussed the question, the National Science Foundation should confine its activities to furthering basic scientific studies and that it should not dilute its effectiveness by supporting studies of directly military or other applied character. To do so would seriously impair the long-term mission of the National Science Foundation without materially contributing to the war effort, since such work can better be done by other agencies. In the long run, of course, additions to basic scientific knowledge will contribute, as previously indicated, to both the wartime and peacetime strength of the country; but short-term results are not to be looked for.

Thus advised and after much debate, the Board withdrew its opposition to what became the Science Advisory Committee of the Office of Defense Mobilization and later the President's Science Advisory Committee. There was no further effort by the Foundation during its early years to assume a major role in military defense activities, but that early debate was reflected in Conant's Foreword to the First Annual Report of the Foundation in which he said:

> The relations of science to war are so well known as to require no elaboration, but what is often little realized is the relation of highly trained scientific talent to the progress of the technological armament race to which a divided world is now committed. Until such time as disarmament becomes a reality, the free nations must be deeply concerned with finding and developing scientific pioneers, for on their efforts we must rely as much for increasing national security in a war-torn decade as for industrial progress in periods of peace.

This means . . . assisting promising young men and women who have completed their college education but require postgraduate training in order to become leaders in science and engineering. To this end a fellowship program has been placed high on the list of priorities by the National Science Board.

There was long precedent for national fellowships in the natural sciences and medicine. Funds provided by The Rockefeller Foundation had been granted by the National Research Council (NRC) to more than one thousand young men and women for postdoctoral study between 1920-1940. In 1945 the NRC started a program of fellowships for study leading to the doctorate; it was supported at first by The Rockefeller Foundation and then by the Atomic Energy Commission. Several thousand students had been thus aided by private and then by Federal funds.

And so there was tradition and available experience when the National Science Foundation awarded its first 569 predoctoral and 55 postdoctoral fellowships in 1952. In order to utilize the past experience of the NRC, the Foundation requested the Academy to administer the selection of 600 fellows from among more than 3,000 who applied. That cooperation continued.

Cooperation such as this with other institutions has enabled the Foundation to accomplish much without becoming a mammoth operating agency. Unencumbered freedom to initiate and support bold ventures without assuming the burdens of administration has been an important concept in shaping Foundation policies. The National Research Centers that are operated for the Foundation by associations of universities and the programs in marine science that are directed by institutes of oceanography are notable examples of such collaboration. Throughout the International Geophysical Year, the Foundation and the Academy collaborated closely in many far-flung undertakings, each aiding the other, and both utilizing the resources and faculties of many universities.

Social Sciences and Applied Research

The long campaign to secure congressional approval of a Science Foundation bill awakened the sponsors of the bill to a widespread need for public understanding of science. The Foundation was reminded of this need each year during the hearings on our appropriation bill. And so, from the early days one of our objectives has been to meet the challenge President Kennedy gave scientists at the Academy Centennial some years later:

> if basic research is to be properly regarded, it must be better understood. I ask you to reflect on this problem and on the means by which, in the years to come; our society can assure continued backing to fundamental research in the

life sciences, the physical sciences, the social sciences, our natural resources. Together the scientific community, the government, industry, and education must work out the way to nourish American science in all its power and vitality. Of course what it needs is a wider understanding by the country as a whole of the value of this work which has been so sustained by so many of you.

As Alan Waterman and I often discussed this need for wider public understanding of science, we recalled the years that he and I had enjoyed the friendship of those in the Senate and House who heard our requests for funds. They never gave us all we asked for, but each successive year they better understood the significance and value of our proposals, even though Alan and I had to consume a good deal of bourbon during evening "educational sessions" with our friends. We learned from them about the needs of their constituents for science and what was the proper role of science in Government.

In those congressional meetings our friends advised us to extend our programs gradually to include more research that dealt directly with social problems and research that was obviously related to national needs. The advice became more forceful as our budget requests grew larger.

During the congressional hearings on Science Foundation bills, there had been much discussion regarding inclusion of the social as well as the physical and biological sciences. I recall that, as a representative of the Committee Supporting the Bush Report, I testified that:

> I cannot think of any field of research in physical science which does not ultimately lead, and usually very promptly, to new social problems. The same is true in biology and medicine. It is important, therefore, that competent social scientists should work hand in hand with the natural scientists so that problems may be solved as they arise and so that many of them may not arise in the first instance.

Donald Young, Chairman of the Social Science Research Council, wisely advised us not to press for inclusion of the social sciences lest we lose support of many legislators who doubted the value of sociologists, social psychologists, and political scientists and were suspicious of their social objectives. In fact, Young, who was a sociologist, refrained from testifying in person.

Congress accepted a "permissive, but not mandatory position." And so the Foundation was not barred from supporting research in the social sciences, but was not encouraged to do so. Today it seems incredible that courage was required to insist on the "permissive policy." That it was wise to do so is obvious now that the natural sciences, medicine, engineering, and the social sciences are closely interrelated. It enabled the Foundation in a recent year to award $17

million in 484 grants which was one-fifth of the total Federal support of research in the social sciences.

During 30 years between the introduction of the Kilgore Technological Mobilization Bill and the program of support for Research Applied to National Needs, there had been much controversy regarding the relations of basic and applied research in the Foundation. Kilgore stressed applied research because it had obvious societal values and satisfied immediate practical needs. On the other hand, Bush urged that "it is pure research which deserves and requires special protection and specially assured support." The successive bills he initiated stressed "basic research which leads to new knowledge, provides scientific capital and creates a fund from which the practical applications of knowledge must be drawn."

I feel confident Bush would agree that a 25-year tradition of primary devotion to uncommitted research is adequate guarantee that Research Applied to National Needs will not drive out "pure" research from the Foundation. I am sure that Bush, an engineer, would approve what James Fisk said in his memorable address at the Centennial of the National Academy of Sciences:

> Far from interfering with "science for its own sake," the applications of science seem steadily to be leading us into realms of greater and greater intellectual and even spiritual challenge . . . . Applied science and technology show directions in which pure scholars may couple to any degree they choose with the human issues and problems of their time. This, too, is not a bad thing for the motivation of men, or for smoothing the path between the ivory tower and public plaza.

As I close I would allude to the unique role, extraordinary competence, and ceaseless devotion of Alan Waterman. President Truman, as I have said, voiced his esteem and gratitude; so have his distinguished successors, Haworth, McElroy, and Stever. I, who was with Waterman 14 years while Chairman of the Executive Committee and of the Board, have special reason for admiration and affection. Under his leadership the staff and the Board of the Foundation became each and together bands of friends working for mutual objectives. "What, after all, is an organization?" asked Vannevar Bush. "It is merely the formalization of a set of human relations among men with a common objective. The form of organization is important. Far more important are the men themselves, and their insistence on working together effectively for a common end." The National Science Foundation has continued to be such an organization.

Footnote: I am grateful to Mabel Bright, my Assistant, and to Vernice Anderson and J. Merton England of the Foundation for assistance and confirmation on recollections.

William A. Fowler

Institute Professor of Physics
California Institute of Technology

for the

National Academy of Sciences Symposium
on the Occasion of the 25th Anniversary
of the National Science Foundation

April 21, 1975

A Foundation for Research

The return on investment in scientific research during the first 25 years of the National Science Foundation is discussed.

This happy occasion is a birthday celebration. It is a time for affectionate reminiscences and optimistic prognostications. It's a time to look back and a time to look forward—but most of all it's a time to sing Happy Birthday—off key or on.

It's a time to look at the stars—not at the budget. It's a time to chortle in our joy, for surely this is one of Lewis Carroll's frabjous days. Callooh! Callay! It's a time for faith—for the belief that there are certain self-evident truths. Among these truths is this: research is a fundamental human activity—it illuminates and blesses our lives. Sure it helps to make a living, but most of all it helps to make living worthwhile—culturally as well as practically. It's time to be an optimist—things cannot get worse; not a pessimist—things cannot possibly get better. Maybe I have that reversed—who cares? It's a Birthday Party. Happy Birthday, National Science Foundation. We salute your Board, your Director and, most important of all, your Staff.

Twenty-five years ago the challenge was direct and explicit. The National Science Foundation Act of 1950 authorized and directed the Foundation "to initiate and support basic scientific research. . ." There were additional mandates; but there it was, the American people, through their elected representatives, created *A Foundation for Research*, and that is the title of this piece. It is not *the* foundation; there are many other agencies and institutions in and out of Government which support research. The word "foundation" is not used solely in terms of

funding but more in its literal sense, the underlying structure on which all else rests. The word "research" is not qualified by the adjective "basic" because, in response to the pressures of our times, the Foundation was authorized to support applied research in 1968 by amendment of the enabling act of 1950.

One hundred and one years ago in *Life on the Mississippi* Mark Twain wrote: "There is something facinating about science. One gets such wholesale returns on conjecture out of such a trifling investment of fact." Those in experimental work may relish Twain's jibe; those in theory may resent it. Be that as it may, the answer to Twain is clear: research is the investment of fact, the investment which may lead, at first to healthy conjecture and speculation, but which ultimately leads to understanding and to wisdom.

The NSF has supported, encouraged, initiated, and counseled a fair share of the research investment in this country over the last 25 years in its many functions as *A Foundation for Research*. The NSF has many other functions, but here it seems appropriate to enquire into what return has this investment brought. This will be the burden of this tale. The choice of research returns to be discussed will be arbitrary but, it is hoped, not capricious. The main subjects will be Earth Science, Molecular Science, Environmental Science, Astronomical Science, and Social and Applied Science. The word *Science* is used here because each of these subjects involves a number of scientific disciplines. For example, Earth Science includes geology, geophysics, geochemistry, and seismology. Molecular Science includes molecular biology, molecular chemistry, and molecular physics. Astronomical Science includes astronomy, astrophysics, and astrochemistry. The remarkable advances in pure mathematics, fundamental physics, and basic chemistry during the past 25 years will not be discussed, and I can only beg your indulgence for the choice of subjects which led to these important omissions. Nonetheless the mathematician, the physicist, and the chemist will find his branch of science thoroughly involved. This piece is about the woods, not about the trees. It adheres to these prescient words and I quote:

"The complete solution of many research problems today requires the correlation of many individual viewpoints approaching the problem from several directions. The Foundation is acutely aware of its obligation to support integrated attacks upon borderline and interdisciplinary problems."

No, those words are not from yesterday's news release. They are from *The Second Annual Report of the NSF* for 1952.

This tale will range beyond the NSF role in the support of research during the past 25 years, but some bias will be apparent. In telling this

story there will be no mention of the names of individual investigators. On this day it would be more appropirate to name the program managers who chose the investigators. Anyhow, as Seneca said, "The reward for a good deed is to have done it."

Earth Science

Where better to begin than here at home on the spaceship which we call earth. It is, indeed, our spaceship; and it is the only possible habitat in the foreseeable future for the billions of human beings who ride it. Thus we must learn all we can about it if we are to conserve and utilize its resources for the benefit and survival of man.

During the lifetime of the National Science Foundation, the Earth Sciences have been revitalized by one of the most rapid, thorough, and potentially practical revolutions in the history of science. Instead of the fixed object which the earth appears to be, to one man during his lifetime, the earth has been shown to be an intricate mechanism with interlocking movements on a global scale which involve its surface and extend deep into the interior. This big picture which goes under the name of continental drift, sea floor spreading, and plate or global tectonics was put together from many sources, but a prolific one among these was the data gathered about the sea floor during the hundreds of seagoing expeditions sponsored by the Foundation. The Deep Sea Drilling Project, using the drilling vessel *Glomar Challenger* under NSF auspices, brought to onshore laboratories oceanic sediment cores that verified and elaborated the new ideas.

For many years the concept of continental drift was an intriguing but controversial one. It did not gain wide acceptance because of many apparent discrepancies in the evidence and because of the lack of a reasonable driving mechanism. It all started with the fit of continental margins, especially the west coast of South Africa and the east coast of South America; but by now a number of other pieces of evidence have been brought to light.

The matching of rocks between continents. Detailed studies in northeastern Brazil and west Central Africa have shown that the older rocks in both continents are similar in composition, age, and structure.

Fossils. The finding of fossils of shallow water reptiles and amphibians in rocks more than two hundred million years old in all of the southern continents, including Antarctica, argues strongly that these continents were once joined together. There is no other logical way for these animals to have spread from one continent to another.

Rock magnetism. The earth's magnetic field periodically reverses; and on land a sequence of chronology of these reversals had been

established for the past six or seven million years. In the 1960's it was noted that the mid-Atlantic Ridge is flanked by magnetic anomalies that are parallel to the ridge, and symmetrical on either side. The pattern of anomalies on the west side of the ridge is virtually a mirror image of the pattern on the east side. These anomalies are apparently also caused by the reversals of the earth's field. Molten rock rises from the mantle along the midocean ridges, cools, and acquires the imprint of the magnetic field at the time of cooling. More molten material forces the cooled material to one side and literally pushes the sea floor apart. As the sea floor spreads, the continents are carried along on plates in the earth's crust. Whether these plates are pushed by the outward motion of the sea floor from the midocean ridges or pulled by downgoing slabs at the continental edges or dragged by convective currents in the mantle is still not perfectly understood.

Seismology. The earthquakes of the world are concentrated in belts or bands. These belts follow the midocean ridges, the margins of some continents, and the deep trenches of the oceans. Detailed studies of the oceanic trenches, especially the Tonga Trench in the Pacific, show that depth of earthquakes gets progressively greater away from the trench reaching down to 700 kilometers. This suggests that, as the crustal plates move away from the ocean ridges, they are also drawn down underneath the margins of the continents or in the deep trenches of the oceans and reabsorbed into the mantle.

The results of the Deep Sea Drilling Project. If the concept of plate tectonics is correct, there should be no part of the oceanic crust that is more than about two hundred million years old, and this part of the crust should be close to the continents and the trenches. Drilling across the mid-Atlantic ridge and in the Pacific has confirmed this. For example, the volcanic basement close to the mid-Atlantic Ridge is only a few million years old; but close to the eastern margin of the United States, for example, the volcanic rocks of the oceanic crust are about one hundred and sixty million years old.

This new unifying concept of global structure and tectonic processes provides a framework for new thinking and research into the mechanisms that shape the earth. Within this framework has arisen a deep understanding of earthquake phenomena which is of the greatest practical importance. First of all, the concentration of seismicity at the boundaries between plates explains the global pattern. There is much more in addition. By combining laboratory experiments on the fracture of rocks with field data, earthquake faults can be described in terms of empirical fracture mechanics, and the radiation pattern of seismic waves can be predicted theoretically. Precursory phenomena prior to earthquakes have been detected, and respectable seismologists around

the world have now joined astrologers, mystics, and religious zealots in earthquake prediction. Put your bets on the seismologists; they may bring home a windfall of untold benefit to human society within the next decade.

Molecular Science

Three billion years ago our mother earth gave birth to life in its simplest form, a molecule that could replicate itself by using building blocks formed by random photochemistry in some aboriginal soup. Within the last million years or so those simple molecules have organized to form a living organism that can understand the molecules themselves and how the molecules build one gene, the unit of heredity, the key to replication and reproduction. This mircale of understanding has come into being over the last hundred years or so, but it is research in the last 25 years which has brought forth a dramatic and coherent picture of the fine structure of the gene, the genetic code, and the control of gene expression. A great synthesis of knowledge has resulted which has conceptually bridged the long-mysterious gulf between the world of the living and the nonliving. This synthesis has led to realization of the continuity between inanimate and animate matter, based on the understanding of the potential for life, inherent in molecular organization.

Developments in molecular biology have been international in origin, and in the United States there has been a number of supporting agencies. Many critical advances were made by NSF grantees. In retrospect it is fitting that the first Foundation award, Grant G-1, "The Effect of Hormones of the Anterior Pituitary Gland on Fatty Acid Metabolism," was in biology. In the infancy of the Foundation the story of the double helix model for DNA, the genetic material, was already known, and it was also known that genes are arranged linearly on the chromosome. Early work supported by the Foundation provided the first proof that mutations within a gene also form a linear array, and that mutations probably involved a single DNA nucleotide. This work laid the basis in part for the further development of molecular genetics.

In another grant program the building blocks of DNA were put together into a predetermined sequence of groups of three, each of which is a code word. This collection of synthetic genes was then used to make a second molecule called messenger RNA. Messenger RNA, in turn, directs the synthesis of a protein-like chain. This new chain was then broken down into its individual building blocks one by one, and each was identified. By identifying each of the building blocks of the new protein, it was possible to break the code of the original DNA and confirm that three nucleotides make one code word and specify a

particular amino acid. It was also possible to establish the direction in which information of the messenger RNA is read, that punctuation between code words is unnecessary, and that code words cannot overlap. How is a particular amino acid positioned properly in the chain? The middleman in this process has been identified as another kind of nucleic acid, transfer RNA. There are different species of transfer RNA, each of which can recognize only one amino acid and a proper code word on a messenger RNA. The primary structure of transfer RNA was determined in a Foundation supported grant. Other work led to the realization that not all cells read a genetic message in exactly the same way and thence to the identification of the *stop* signals, which mark the spot at which synthesis of proteins stops.

Environmental Sciences

The National Science Foundation has played the leading role in initiating comprehensive studies of extensive ecosystems. Although one view of ecology has always been synthetic and holistic, it was apparent in the early 1960's that most studies were not sufficiently comprehensive and quantitative to achieve more than a generally descriptive level. After years of modest support of Systematic Biology, NSF took a major initiative in supporting the Biome Programs generated under the International Biological Program. The investment in the Systematic Biology began to pay off.

While it cannot be said that the attempt to construct a total system model has been successful, there has been considerable success in modeling component parts. The models developed in these studies have found surprisingly early use in addressing a variety of land management problems, simply because they are the first tools available for making reasonable projections of the consequences of management alternatives. Most important, however, it is clear that a new era has been initiated in which ecology will be more adventurous, more quantitiative, and will direct more attention to the construction of models for understanding and predicting the behavior of total systems.

Our immediate environment is the land, the sea, and the air; but the deep core of the earth produces a magnetic field around us which deflects penetrating particles from the far reaches of the Galaxy. Our environment is the Universe. One of the most important trends during the life of the Foundation has been the developing recognition, shared by scientists and the general public alike, that the environment is in fact a single entity, a gigantic system. Environmental Science is the study of all natural processes, their interactions with each other and with man. The National Science Board and the Staff of the Foundation have been well aware of the many important probelms such as the removal of

sulphur from smoke, the recycling of industrial wastes, and the protection of open spaces and the technological and institutional changes needed to change them; but they have also been greatly concerned about the advances required in the science of environmental systems if the basic knowledge and understanding needed to help resolve problems of public interest are to be provided.

Astronomical Science

And now we lift our eyes from the earth to the heavens—to the planets, the sun, the stars and the interstellar medium surrounding them, the galaxies, and the vast reaches of space and time. It goes without saying that in astronomical science in the past 25 years it has been the space adventure from Sputnik to Appollo that has captured the popular fancy. It goes without saying, too, that the National Aeronautics and Space Administration (NASA) has played the primary role in this incredible human venture. At the same time NSF has played a supporting role. For example, NSF funds built the mass spectrometer, Lunatic I, used in the strontium-rubidium dating of lunar rocks and soils which showed that the moon and the meteorites and inferentially the earth and the sun were the same age, approximately four and one-half billion years old. We do not know how the solar system started, but we jolly well know when!

Over this same 25 year period there has been a veritable explosion in astronomical science, and here NSF has played an important and in many ways the leading role. Visual astronomy is thousands of years old, and optical astronomy is 366 years old. Radio astronomy is 44 years old, but is has only been in the last 25 years that radio astronomy has become a mature science. Witness the development of Very Long Baseline Interferometry, which gives us exquisite small details of the structure of enormous radio sources. Here NSF has played a major role. This same 25 years has witnessed full scale extension of optical astronomy into the infrared and ultraviolet and the birth of microwave and molecular astronomy, X-ray astronomy, gamma-ray astronomy, and neutrino astronomy. In addition, cosmic-ray studies, no longer in the forefront of elementary particle physics, have become an integral and important part of astronomical science. We can now "listen" to the "music" of the spheres over many octaves and not just within one. The celestial message is borne not only by photons, but also by neutrinos and by energetic nucleons and nuclei.

In order to observe and detect over a wide range of radiation and particle energies, it is necessary to have observatories equipped with large telescopes or other detectors and sophisticated auxiliary instrumentation. Very early in the life of the Foundation it became clear

that National Centers of research were necessary to meet national needs for research in astronomy and the atmospheric sciences requiring facilities, equipment, staffing, and operational support that are beyond the capabilities of private or State institutions and that could not appropriately be provided to a single institution to the exclusion of others. Unlike many federally sponsored research laboratories, the NSF-supported National Research Centers do not perform specific research tasks assigned by or for the direct benefit of the Government. They are maintained for the purpose of making available, to all qualified scientists including their own staffs, the facilities, equipment, skilled personnel, support; and other resources required for the performance of independent research of the scientists' own choosing. This has all run parallel to NSF support of users' groups at the national accelerator centers built by the Atomic Energy Commission.

The Foundation supports four astronomy centers (National Astronomy and Ionosphere Center at Arecibo, Puerto Rico; Cerro Tololo Inter-American Observatory near Santiago, Chile; Kitt Peak National Observatory at Tucson, Arizona; and National Radio Astronomy Observatory (NRAO) at Green Bank, West Virginia) and one atmospheric research center (National Center for Atmospheric Research at Boulder, Colorado).

At the same time the Foundation has provided an increasing amount of research project and instrumentation support for ground-based astronomy in universities and other private institutions, both national and international. New, up-to-date instrumentation is essential in research activities in all fields. Here the term ground-based must not be taken too literally. For example, the stratoscope balloon-borne telescope project, with NSF support, obtained pictures of planets and galaxies at the high resolution of one-tenth of an arc-second. Grantees of NSF have sent their instruments far and away in rockets and satellites. Today the Foundation supplies well over half of the total Federal support of research in astronomy.

As was mentioned above, there is no point in parceling out credit here and there. Rather it is the overall picture to which NSF has contributed its fair share, which merits our attention; and what a picture it is. Our view of the Universe has widened and deepened with astronomical discovery after discovery in the past quarter of a century. First of all consider the secrets wrung from observations of the interstellar clouds of gas and dust that permeate our Galaxy. In 1951 came the discovery of the 21-centimeter line of neutral hydrogen, in 1963 the hydroxyl radical was observed, and in 1968-1969 the molecules of ammonia and water. Astrochemistry came into being. Approximately 150 lines from 33 different molecules, some with rare

isotopes, have now been observed; 27 of these were first detected by NRAO telescopes. I'm glad to note that ethyl alcohol has finally been observed—I was beginning to wonder whether Heaven was such a great place after all. But in all seriousness, the interstellar medium is of the utmost importance to us, not only because it is the site of the formation of stars like our sun, but also because it contains the simpler organic molecules whose further buildup on planets may lead eventually to the development of life.

In his brilliant Robertson Lecture earlier today Professor Martin Rees spoke about the many exciting developments in astronomical science over the past 15 years. These include the discovery of galactic X-ray sources in 1960, quasars in 1963, the microwave background radiation in 1965, and pulsars in 1967. NSF research has played a major role in subsequent developments. In fact if I were to identify the astronomical National Centers with major contributions in one program only it would be quasars at Kitt Peak, pulsars at Arecibo, just as it has been molecules in space at Green Bank and solar physics at NCAR. An aside is appropriate here. Quasars represent the violent transformation of as much as one million solar rest masses into energy in the form of magnetic fields and relativistic electrons. Is it annihilation energy, nuclear energy, gravitational energy? We still do not know, and I for one believe that the solution of this celestial energy crisis, when it comes, will tell us something about energy generation and energy transformation of potential application to our terrestrial energy problems.

These exciting observational discoveries tend to overshadow the advances simultaneously made in our understanding of stellar evolution and of the nuclear processes associated with the various stages of that evolution. The realization during the 1950's that the Red Giant Stage of stellar evolution involved helium burning which transforms helium into carbon and oxygen was just as far-reaching as the discovery in 1920 that the Main Sequence Stage involves the conversion of hydrogen into helium. This fundamental understanding of the Red Giants has been followed by deeper appreciation of what occurs in the advanced stages of stellar evolution—in the variable stars, in the so-called horizontal branch, in the Red Super Giants, in the Blue Super Giants, in Novae and Planetary Nebulae, and in Supernovae. The answere are not all in yet, but the conceptual framework is there.

However, the rapid experimental and observational advances have not been completely assimulated theoretically. Some think there exists a crucial situation in our understanding of the physical universe, and I cannot refrain from telling a story if only to put my "gee whiz" attitude about astronomy in perspective. A friend of mine, who shall be

nameless, takes it all very seriously and some time ago, working under an NSF grant, wrote a paper entitled "The Developing Crisis in Astronomy." Sure enough, when the paper was published there was the tell-tale asterisk after the title referring to a footnote which read, "Supported in part by the National Science Foundation." Well, you can't win 'em all.

Social Science and Applied Science

In an entirely different context, in the story of the death of a young President, who earlier graced this Academey's centennial ceremonies, William Manchester wrote, "Research, of course, is no substitute for wisdom." The "of course" is quite right. But let there be no misunderstanding. If we are to avoid the destruction of nature and the degradation of mankind *we must learn how to transform research into wisdom.* Social Science and Applied Science in different ways strive toward this goal.

Social Science was not included in the mandatory language of the NSF act in 1950, but research in the social sciences has been assisted since late 1953, beginning with subareas close to the mathematical, physical, and biological programs. The close bonds between the social and natural sciences have been since then one of the hallmarks of NSF activities.

Engineering Science has been part of the NSF program from the beginning. Engineering Science has aimed to increase the understanding of the principles and concepts that are common to and underlie a wide variety of technological problems.

Materials Research has been an NSF function since the beginning, and the program was considerably augmented when the Foundation assumed the responsibilities for the Interdisciplinary Materials Research Laboratories from the Department of Defense in 1971.

Thus a firm groundwork was laid in the social and applied sciences for the *Research Applied to National Needs* (RANN) program that was developed in response to the applied research authorization granted in the amended NSF Act of 1968. *Interdisciplinary Research Relevant to Problems of Our Society* (IRRPOS) was begun in 1969, and it was only necessary to sharpen and focus research on selected environmental and social problems and on opportunities for future technological development in order to respond to the legitimate demands of a society for which the fruits of research had been, speaking without prejudice, a mixed blessing. Basic to the concept of RANN from the beginning was the eventual transfer of programs to mission-oriented agencies of the Federal Gvoernment and to industry. Again, one example must suffice.

Between 1971 and 1974, RANN led in the effort to define a solar energy research program to more fully understand and exploit this inexhaustible resource with which we are blessed. The payoff came with the formation of the *Energy Research and Development Administration* (ERDA) to which RANN was able to transfer funds, staff, and know-how in solar energy technology. At the same time RANN was able to continue with concentration on innovative, long-range, high-risk, high-payoff projects in solar energy research. The NSF is indeed responding to national needs.

Conclusion

This has been one man's account of the return on the American people's investment in *A Foundation for Research*. There have been failures as well as triumphs, but those are for others to record. Research has enriched our lives and nurtured our livelihood, but it has also brought inevitable problems which hopefully in these next years it can help to ameliorate. All in all it has been a 25 year success story with, best of all, rich promise for the future. We will fulfill that promise only if we succeed in *transforming research into wisdom in the compassionate use of knowledge in the affairs of mankind.*

And so, in conclusion—once again, we salute you, National Science Foundation; Happy, Happy Silver Anniversary! You deserve this fervent wish. If there are any clouds in your future, may they all have silver linings.

Dr. Joseph B. Platt
President, Harvey Mudd College

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Science Education—Who, Why, and How Did It Work Out?

The National Science Foundation Act, as amended, authorizes and directs the Foundation to initiate and support basic scientific research programs, to strengthen scientific research potential programs, to develop science education at all levels, and to award graduate fellowships in science. In the last quarter century the Foundation has expended about $1.5 billion in support of science education programs and graduate fellowships. Who had been supported, why were they supported, and what came of that support? Let us begin with the "why."

Dr. Bronk has dealt with the development of the idea of the National Science Foundation from President Roosevelt's 1944 letter to Dr. Vannevar Bush through the early years of the Foundation itself. In *Science—The Endless Frontier,* two concerns were uppermost in recommendations about science education. In the short term, war service had interrupted the education of some 150,000 potential engineers and scientists who would otherwise be in the labor force with baccalaureate degrees, and by 1955 there was also an expected "deficit" of some 17,000 Ph.D.'s in engineering and science. The health of science and technology in the United States required that these young people be brought back into the scientific community, that "the generation in uniform must not be lost." In the longer term, the highest quality of research and development activity would require that science education, at both undergraduate and graduate levels, be available to those of greatest ability and not simply to those who could afford it. President James B. Conant of Harvard University (later to become the first Chairman of the National Science Board) was quoted: ". . . in every section of the entire area where the word science may properly be applied, the

limiting factor is a human one. We shall have rapid or slow advance in this direction or in that depending on the number of really first-class men who are engaged in the work in question. . . . So in the last analysis, the future of science in this country will be determined by our basic educational policy." The report added the caveat, "There is never enough ability at high levels to satisfy all the needs of the nation; we would not seek to draw into science any more of it than science's proportionate share."

The GI Bill was the greatest single help to the generation in uniform, in whatever field the GI chose to study. If he or she hoped for graduate study beyond the GI entitlement, help in the late 1940's came from pre-NSF sources—including in particular the fellowship program funded by the Atomic Energy Commission (AEC). Graduate research assistantships funded through the Office of Naval Research (ONR) were also of great help in preventing the loss of the generation in uniform. But by 1950 the ONR had less money and the AEC had more obligations. The most urgent educational task for the National Science Foundation when it began operations was to support graduate students of highest ability in engineering and the sciences, without respect to wealth.

Since 1951 the National Science Foundation has awarded predoctoral fellowships to approximately 15,000 young people. At no time has the Foundation's predoctoral fellowship program supported more than 6 percent of graduate degree candidates in engineering and the sciences. Evaluation has shown that these predoctoral fellows—the first few thousand of whom are now in their mid-forties—have done well professionally. They are more apt than their contemporaries in graduate school to have earned the doctorate, and were younger when they did so. They have subsequently published more, and they are more apt now to be actively involved in research or development.

Not too many Members of the National Academy of Sciences ever had the opportunity to be National Science Foundation predoctoral fellows. According to my count, only 68 Academicians were still undergraduates in 1949. Seventeen of you, or 25 percent, were later National Science Foundation predoctoral fellows.

A great deal has already come from the contributions of NSF predoctoral fellows to the vitality of science in the United States.

The counterargument is that young people of this ability would in any event have made a great contribution. What the NSF funding did was to make available to others the support these students would have been awarded and, hence, really made possible the graduate education of less promising students. Perhaps. But I know from personal ex-

perience students who had decided against graduate work until the NSF awards came along; or who were enabled to go where they chose rather than where they could afford; or who saved a year in earning their doctorates. So do most of you in this audience.

The fellowships gave a few of the best not only support but also greater freedom to plan their own way.

In the early years of the National Science Foundation, Dr. Alan T. Waterman and his staff began exploring many other activities through which the Foundation would make major contributions to the strength of graduate education. A program of postdoctoral fellowships was begun in 1952. In the next two decades over 3,000 of the most promising young research people had the opportunity to broaden or extend their research experience before taking permanent jobs. It became clear that some established research people could be "transplanted" to different laboratories and combine the best of two differing research traditions. Over 15 years some thousand senior postdoctoral fellows were appointed.

I need hardly remind this audience that the whole national climate for science education changed dramatically in October 1957. After Sputnik much of the Nation concluded we were lagging behind the Russians dangerously in the availability of scientists and engineers; what was worse, unless we woke up, the gap would widen.

Funding for the NSF science education programs soon moved from millions of dollars per year, before Sputnik, to tens of millions per year thereafter. Graduate education was seen as a major bottleneck. A dozen universities received over half of the Federal pure research funds and enrolled most of the NSF predoctoral fellows. Accordingly, in the early 1960's the NSF began the effort to help lift the number of first-rate academic centers of science from the 15 to 20 then existing to twice that number by 1975. Part of this effort was the NSF graduate traineeship program, in which the institution chose the graduate student to be supported by NSF funds, rather than the other way around. By the late 1960's twice as many graduate students were supported by traineeships as were by fellowships.

Graduate education in the sciences is mostly an apprenticeship in research. There is no sharp line between the support of research and of graduate students. Much of the research supported by the NSF during this last quarter century would simply not have been done without the graduate students who were learning how to do it. Likewise, the Foundation supported graduate education through helping to build and equip laboratories, through the payment of research assistantships which kept graduate students alive, through support of advanced

science seminars in which graduate students and research faculty taught each other, and through much else. Accordingly, during this quarter century, what came of NSF support of graduate education in engineering and the sciences was perhaps 5 percent of the current group of engineers and scientists under age 45, including many of the best, perhaps severalfold more. It depends on where one draws the fuzzy line.

To return to the caveat in *Science—The Endless Frontier*, during the last quarter century, the number of graduate students in the United States, in all fields, has increased almost fivefold. The fraction of these graduate students enrolled in engineering and the sciences has increased very slightly. The Nation *has* attracted more able young people into science and engineering. but nearly equivalent gains have been made in the social sciences, the humanities, or the learned professions as a whole.

The real concern of the early 1960's was that too few young people of high ability were even interested in science. The National Science Foundation had already begun to explore ways in which the Nation could attract into careers in engineering and science a full share of the ablest of our young people, without regard to family income or background. That was the second educational charge in *Science—The Endless Frontier*. There was little the Foundation could do, financially, to subsidize the pre-college education of poor children with high scientific or technical potential. But the Foundation could and did do a great deal about improving the competence of teachers and the quality of teaching at the secondary and primary levels. For 30 years, university mathematicians and scientists had sputtered about the quality and quantity of subject matter preparation of most high school teachers of science. A few groups—notably some of the scientists of the General Electric Research Laboratories in conjunction with Union College—had set up summer programs to teach current science to high school science teachers. The results were encouraging. In 1953 the National Science Foundation provided funds for two summer institutes to upgrade the subject matter preparation of *college* teachers of mathematics and chemistry. By 1954 high school teachers were included. Through 1973 the National Science Foundation supported more than 7,000 summer institutes to teach science to teachers—mostly high school teachers but also teachers from elementary through graduate school. Between a quarter and a half of the 300,000 secondary school teachers of mathematics and science have attended at least one institute.

Many of these institutes have taught teachers new course materials that were prepared under NSF sponsorship through the Course Content Improvement Program, of which more later. Other in-

stitutes have been developed by universities for the needs of school teachers of their areas. These institutes have been optional. The teachers attended institutes only if they chose, and their school systems took advantage of their new skills only if they chose.

What came of all this? To the extent that institutes repair deficiencies in the preparation of teachers, a better long-term solution is adequate subject matter preparation for the teacher in the first place. Changes in certification requirements and in science teaching curricula give some evidence this is happening. To the extent the institutes extend or update a good basic preparation, there is a continuing need for such in-service training. One can lament the normal preparation of teachers or do something about it. The institutes have done something about it on a significant scale and the experience of the institutes is beginning to change the normal preparation.

Beginning in 1954 the Foundation supported programs to develop new science teaching materials. Characteristically, a program has brought university scientists together with high school teachers to develop a text followed by a teaching trial, then a revised text, plus the development of teachers' manuals, laboratory experiments, teaching movies, and so on. Dozens of such programs have been supported, from kindergarten through college, from algebra to zoology. The major ones include the Physical Science Study Committee, the School Mathematics Study Group, the Biological Sciences Curriculum Study, the Chemical Education Material Study.

What came of all this? We do know that each year about one-quarter of the high school students in the United States are taking science courses based on these materials. Over their school years, many students have several such courses; many have none. The level of preparation of entering college students, in mathematics and the sciences, has increased significantly since 1960. The high school preparation of college-bound students now includes more modern material, frequently at greater depth.

Five years ago the Advisory Committee for Science Education reported to the National Science Board: "We believe that the course content improvement activities of the NSF have had a much larger impact on primary and secondary education in the United States than is generally appreciated, and the impact has been good. Primary and secondary education in the United States is a big business. It includes some 51.5 million students, over 2 million teachers, and decisions are made in some 20,000 school districts. The total expenditures for primary and secondary education in the United States during the decade from 1959 to 1969 came to about $250 billion. The amount of money the NSF put into the course content improvement activities for

primary and secondary schools, over a slightly longer period, was less than $100 million, or about four cents on every one hundred dollars. It is not easy to revise either the content or the methods of teaching, and we believe no other single cause has had as much impact on the revision of the high school curriculum over the decade."

The course content improvement activities had a great deal of help from other funds. The teachers' institutes taught many thousands of teachers these new materials. Many school districts made sizable investments of time and money. The materials diffused into the textbook industry and influenced many courses not supported by the NSF. The impact of these programs also went far beyond the fields the NSF has supported. Similar course development activities, funded by other sources, have influenced the teaching of languages, of social studies, and other fields.

The National Science Foundation has also supported a good many activities intended to improve the teaching of university and college students in mathematics, the sciences, and engineering. As this audience well knows, faculty members are an independent lot, and no nationally sponsored freshman physics course is likely to be generally adopted. But many new techniques and teaching aids have been sponsored by the NSF which have diffused broadly though the university science teaching community—for example, computer modeling techniques and methods of self-paced instruction. Tens of thousands of venturesome college students have had their first real taste of scientific research through the Undergraduate Research Participation Program. I can assure you that an undergraduate author of an article in a scientific journal is a proud author. Over the decade of the 1960's, much of the help in the improvement of college teaching came in the form of institutional grants under the College Science Improvement Program, which enabled many colleges to design and carry out their own plans for the improvement of science instruction.

The list of programs the National Science Foundation has supported to improve the teaching of science in the United States is an encyclopaedic one, and I can touch only on the major highlights. The Foundation currently supports two major experimental ventures in the use of computers for science instruction; plus any number of smaller scale programs to enrich science teaching or reduce its costs through the use of computers. The Foundation has made possible some remarkable programs for gifted high school science students; I have been startled to see high school juniors, in 6 weeks, learn enough observational astronomy, calculus, and computer programming to observe and calculate the orbits of previously uncatalogued asteroids. Over recent years the Foundation has supported student-originated studies at

the college level, many of which have made useful original contributions. Some promising beginnings have been made in developing science education programs tailored to the needs of ethnic minorities, including native Americans. From the beginning, the Foundation has been willing to help experiments designed to improve the teaching of science, and many of these experiments have developed methods that do change teaching for the better.

The total investment made by the Foundation has been tiny in relation to the costs of education in the United States. In 1970, for example, the NSF expenditures for science education came to 0.2 percent of the national costs of education, and to 1.5 percent of the Federal outlay of educational funding. Accordingly, the NSF has supported at most a small fraction of the people involved—5 percent of the most able doctoral candidates, one-tenth of the professional education of one-quarter of the high school teachers of science, a curriculum development group here, a computer experiment there. In short, support has been targeted on the individuals or groups most likely to have an impact. The general support of education has been the business of other Federal agencies.

My remarks so far have dealt largely with the first 20 years of the National Science Foundation's science education program. The last 5 years have been different. The staff of the Foundation and their advisers began to expect changes in the late 1960's, and in my next remarks I will draw on these discussions—in particular on the 1970 report of the Advisory Committee for Science Education.

Let me first place science education in the general context of all of education in the United States. We all know that our society has been transformed in this century, and that education has been a major precondition for the transformation. Since 1900 the labor force has changed composition from 38 percent farm workers to the present 3 percent; white collar workers, including us, have gone from 18 percent to 48 percent. In the last quarter century alone disposable personal income has increased 70 percent from $1,628 per capita to $2,775 in constant (1958) dollars. Many economists hold that our national investments, in research and development and in education, are major sources of the growth in the economy, although they disagree on the proportions.

The "knowledge explosion" is an essential precondition. Library holdings in the United States have doubled every 18 years since the time of Thomas Jefferson. The number of books and articles in the sciences has doubled every 10 years in this century. The knowledge explosion, particularly in the sciences, has substantially outstripped the population explosion.

Education has made this information available and useful to the individual and to society. Three techniques have enabled us to make useful the growing amount of information. We have educated a larger fraction of the population at each level of education. In the 1870's about 7 percent of our population was educated beyond the sixth grade level; in the 1970's over 95 percent. In 1870 about 2 percent of young people entered college and about 1.3 percent earned degrees. In 1970 college enrollments were 48 percent of the 18- to 21-year group, and the number of baccalaureate degrees conferred amounted to 24 percent of the number of 21-year-olds. And, the annual number of earned doctorates in science in American universities has increased from one in 1870 to about 30,000 in 1970.

The second technique follows from the first: We have educated any one person longer. In 1870 the average person entered the labor force with 7 years of formal schooling; today the average is 13. For some specialties, 4 to 6 years of postdoctoral internship are required for professional practice—20 years of formal schooling.

The third technique is specialization—any one individual is responsible for a smaller fraction of the total of available information. Specialties are harder to quantify, but I estimate we have been doubling the number of specialties every 10 to 15 years.

It was clear in the 1960's that these techniques, which have served us for a century, were incapable of extension by more than a few decades. We cannot again double the fraction of our young people entering high school—95 percent crowds the upper limit. It may not even be desirable to double the fraction entering college. Doubling the length of formal education would commit one-third of the life span of the average worker to full-time schooling and over half of the life span of the most educated. And specialization now makes it increasingly difficult for most of us to understand what others are doing.

It was not clear in the 1960's which social and economic forces would limit these techniques. We know now. The annual crop of 18-year-olds increased 37 percent in the last decade and will increase 6 percent in this decade—*decreasing* thereafter. The fraction of these 18-year-olds who want to go to college is also leveling off. The demand for primary and secondary school teachers has dropped abruptly, and the demand for new doctoral level faculty in college and university teaching is also dropping. The share of our gross national product committed to current costs of higher education went from 1.1 percent in 1960 to 2.2 percent in 1972, and has now dropped to 2.1 percent. The share of our gross national product committed to research and development activities, which was 2.9 percent in 1965, is now around 2.3 percent.

Shifting national priorities intensified the economic and social reaction to the educational expansion of the 1960's. The energy shortage, environmental concerns, and growing social insurance costs demanded more of the available money. But the three techniques that served this Nation so well for a century—teaching more people, teaching them longer, and specialization—would in any event have begun to level off in this decade.

What has happened to the National Science Foundation's program in science education over this period? It has declined. What should be the response to this period of transition? My two tours of duty on the Foundation's Advisory Committee for Science Education have given me the opportunity to hear these issues discussed and to see new programs created. I claim no originality in what follows, but speak only for myself.

I believe President Conant's analysis continues to be right. The long-term health of science in this Nation depends primarily on the number of first-class minds we continue to recruit into research; the intellectual resources we can call upon for new solutions to our national needs continue to depend on new knowledge. It is true that the academic market for science Ph.D.'s is disappearing. It is not yet clear where new markets will develop. As more of our scientific manpower is deployed to work on such urgent problems as alternate energy sources, I hope some established research workers will turn their attention to the urgent problems and some young people of great promise can be attracted into the long-range improvement of our knowledge of nature. It remains true that we can ill afford to lose a generation, in uniform or not.

The National Science Foundation continues to support its fellowship program, although at a reduced level. It now also supports some experimental efforts to help established research workers to move into more applied fields in the solution of societal problems.

The second recommendation from *Science—The Endless Frontier* also continues to be important. The United States has done better than any other nation in offering access to education to all its people. But it continues to be true that young people from the top fifth of the national income distribution are much more likely to attend college than are those of equal ability from the bottom fifth. We need to draw on all our talent, not only to build a productive society but also to build a more stable one. Inability to afford education is an important reason for our present imbalances, but so are other factors affecting children of poor families: inadequate preparation, the low expectations of these young people and their families, the lack of role models. We have few blacks, Chicanos, or

American Indians who are professional scientists and engineers for all these reasons. We also have few women.

What the National Science Foundation can do about this problem of imbalance is to find ways to attract more young people from underrepresented groups into careers in science and technology. A variety of experiments are now supported by the Foundation to learn how. If the Nation decides to support more universal access to higher education and in particular to careers in science, the National Science Foundation may provide the experience to make better use of that support.

Beyond these two continuing charges, there are other assignments in science education that are becoming urgent, and which are of the type the Foundation is authorized and directed to undertake. The pressing problems that face us nationally—pollution, energy shortages, and the like—generally require new technology but will be solved or ameliorated through the political process and the marketplace. The engineers and scientists who can best contribute need to be able to understand and work with experts in these areas. New educational programs designed to develop problem-solvers of this type are needed; they are apt to be interdisciplinary and to depend on real or simulated work-study experience. The National Science Foundation is supporting a number of such experiments.

Job opportunities in engineering and the sciences may increase over the years ahead, with most of the growth being in problem-oriented applications of science. But the new governmental jobs are just beginning to appear, and we know little as yet about the industrial needs or which industries will respond to the new requirements. A time of changing career patterns is a particularly risky one in which to make manpower forecasts, but it is also one in which young people interested in pure or applied science need all the help they can get in choosing possible careers. The National Science Foundation is undertaking work of this sort through its Manpower Characteristics System.

New methods of teaching or learning that improve benefits or reduce costs of science education are in great demand. The Foundation is supporting a variety of such experiments, from computer-assisted instruction through completely restructured learning environments. These are all pilot programs aimed at discovering better methods of adjusting to the decade of transition now upon us.

A major new challenge, it seems to me, is to improve the science education of those who do not aspire to be professional scientists. Scientists and engineers constitute about 2.1 percent of our civilian labor force. Much of the rest of our labor force, from airline pilots to coal miners, uses sophisticated and changing technology. The ability of

these people to adapt to change depends in some considerable part on an understanding of basic scientific concepts. For all of us, as citizens, the issues on which we must vote increasingly involve choice among technologies. It is, of course, true that scientists and engineers need to learn more of economics and political processes if we are to help with societal problems. It is also true that legislators and voters could be of more help with societal problems if they learned more of science and technology.

There are two problems in making more science education available for nonscientists. The first is to find a nonscientist who wants to learn some science. The second is to have the right kind of teaching materials at the right place at the right time. Recent experiments which the National Science Foundation is supporting give some help on both scores.

Community colleges provide an excellent test bed for such experiments. Community college enrollment is still growing, and they want help. Their students come at all hours, they include a mixture of vocational and university-bound students, of the young and middle aged, of technical and nontechnical students. Many community colleges are venturesome in trying computer-assisted learning, televised instruction, videotapes, and other forms of teaching that can reach a much larger public on demand. For instance, a course on "Man and Environment" prepared by Miami-Dade Junior College in Florida has now been used in some 20 cities and has been taken for credit by more than 12,000 students. The course cost $1.1 million to prepare, so the cost of materials per student is now under $100 and dropping. Televised use of the course by the Portland Community College at Portland, Oregon, gave Nielsen ratings indicating it was reaching 50,000 persons per week, of whom some 200 were enrolled for credit. Those who have seen the *Nova* series, which the Foundation is helping to support, or *The Ascent of Man*, can appreciate the usefulness of first-rate materials in reaching unsuspected audiences. The years ahead are likely to see a number of developments that make good materials available to a learner at his choice and convenience. Video discs, cable television, and computer-assisted instruction can be expected to expand these opportunities as demand increases and at decreasing unit cost. The costs will in general be borne by the user, the employer, or the local college system. The National Science Foundation has, in my opinion, a real opportunity to assist pilot projects that set standards of scientific accuracy in these new fields.

In summary, the National Science Foundation has done much in the last quarter century to encourage scientific talent, to develop new teaching materials, and to enable science teachers to do a better job. The

Foundation has not supported science teaching in general; support has gone to selected programs that have influenced the ongoing science teaching activities in the Nation. The last 5 years have seen major changes in the tasks of education in the United States and in the expected level of support for these tasks. The National Science Foundation has the major obligation of maintaining the health of science, and the teaching of science continues to be an essential part of that obligation. Through its experience and its style of operation, the National Science Foundation can also make a major contribution to the scientific literacy all of our citizens will need to choose wisely among the possible futures the next quarter century will reveal.

I do not know what the next quarter century may hold. We may well be more concerned with adapting than with growing. I do not know what strategy we should use in preparing for the next 5 years versus the next 25. The knowledge we now have is substantially the greater because of research the NSF began supporting 25 years ago, and our ability to develop and use that knowledge is substantially the greater because of the people whose education was enriched by NSF science education support.

Dr. H. Guyford Stever
Director, National Science Foundation

for the
National Academy of Sciences Symposium
on the Occasion of the 25th Anniversary
of the National Science Foundation
April 21, 1975

Whither NSF?—The Higher Derivatives

We are here to celebrate an anniversary—the 25th year of the National Science Foundation. As my colleague, Willy Fowler, has described it, this is a birthday party, and as such it is time both to reminisce on the past and look to the future. My assignment is to look ahead. With all due respect to the previous speakers, I think I have been saddled with the harder job. Nevertheless, I'll try to give you some idea—my own assessment—of where we may be headed. I do not expect that you will all agree with my prognosis. And perhaps in the course of these remarks I will be raising more questions than I will be answering. But if so, I can think of no better time to raise such questions and to bring into open discussion some of the hard issues that all of us in the scientific community, as well as those who are concerned with the future of science as a social force, will be facing in the years ahead.

My major thesis in approaching this discussion of possible futures is that in the structure and support of our scientific and technological enterprise, we of the science and engineering communities have witnessed a major change and now face a strong challenge in our relationship with society. It is obvious that the social environment in which science is performed has changed, is still changing, and will undergo even greater change in the coming years. Such changes will be economic, social, and political. The extent to which scientists and engineers become actively and constructively involved in these evolutionary processes could determine not only the outcome of their professions and of science itself, but of nothing less than the fate of our current civilization. I would like to devote some of my comments to the reasons for these changes and some of the responses that may have to be made by science and scientists. From these you may draw several conclusions about the shape of our enterprise in the years ahead.

Perhaps we should begin with some thoughts on the economic aspects of science and technology since economics is a subject on many minds today. We as scientists know that a great many important scientific discoveries have been made, and important theories arrived at, through research that was relatively low in cost. We might call these "intellectual-intensive" projects if we resorted to economic jargon. Much good research today still falls in this category. But much does not. And the cost of conducting that other segment of the Nation's scientific and engineering business has reached capital-intensive proportions. Furthermore, we are just seeing the tip of the iceberg. Here I am speaking of work in both the most basic science and the most advanced applied engineering. For example, in basic research a new accelerator is now a 250-million-dollar investment with a multimillion-dollar per year level of effort thereafter. In applied research and development we must recognize the multibillion-dollar costs involved in such projects as the construction and testing of the demonstration breeder reactor. Similar large investments lie ahead in other energy fields. We should not underestimate the economic outlays that will be required for the full-scale demonstration and application of coal gasification and liquefaction as well as the cost over the next few decades of making the transition to a solar and fusion age. These too will become multibillion-dollar projects for the government, and eventually involve trillion-dollar enterprises for the Nation as a whole. Today's programs in their incipient stages give us only an inkling of the enormous long-range costs in both public and private investments which will be required to bring all the aspects of that age to their fullest fruition.

Unrealized by many people is the fact that we face similarly large investments in advancing and making the fullest economic and humane use of the fine work being done today in the biological and chemical fields—particularly as they relate to the world's food problem and the revamping of industry to meet the requirements of global growth within the confines of the new environmental criteria being set. We are now a world of four billion people. Should we achieve the demographic feat of leveling off between seven and eight billion as we enter the next century, we will still have to come up with some miraculous accomplishments in agricultural yields, nutrition improvements, pest control, fertilizer and water developments, and land utilization even to maintain such a population at a subsistence level. However, even present evidence that a large part of this population will not settle for mere subsistence should warn us that unless we can mesh our industrial and environmental requirements at a much higher level than today, we face pressures that could lead to a period of social and political chaos unprecedented in human history.

To me, all this points to a tremendous growth of economic involvement for science and technology and a related growth of responsibility and accountability for scientists and engineers. We are going to be involved as never before in the economic success or failure of this country and the rest of the world, and we are going to be taking the praise and the blame for far more than we have ever bargained for. We now must get used to the idea of such involvement—and not only economically, but ethically and socially, as I will dwell on in a moment.

Another reason for this direct and intense involvement, in addition to the economic costs and social expectations tied to scientific and technological advances, rests in the shrinking time span between the understanding and widespread application and influence of a scientific phenomenon. It took roughly 2,000 years to capitalize fully on some of the discoveries of the ancient civilizations. It took a few centuries to realize many of the technical concepts that came out of the Renaissance. It took 50 years to reap the benefits of the Industrial Revolution. In the post World War II period, the time between a scientific discovery or major invention and its wide utilization shrank to perhaps 10 to 15 years. Today the compression of time between a scientific advance, the proposal of an idea based on it, and its widespread application has reached a point where this process is operating within the attention span and the operating lifetime of most persons in positions of political and economic power. One of the most dramatic examples of this rapid interfacing of science and politics is the fact that only weeks after the announcement of the theory that man's release of fluorocarbons into the atmosphere may be dangerously affecting the ozone shield, there was already Congressional activity on the matter. As Robert Heilbroner stated in *The Future as History*, "Advances in science and technology have rewritten the very terms and conditions of the human contract with no more warning than the morning's headlines." And if I may add a footnote to that observation, any retreats, such as from the use of DDT, that we make in pursuing science and technology will have a similar short warning.

In addition to this time span phenomenon, there has also been an increasingly close linkage between the physical and social effects of scientific advances. The combination of these effects has contributed to a certain politicizing of science that will be a major characteristic of our activities for years to come.

I think all of us here today can see this in so many ways in the activities already taking place, and growing, in the arena of science administration and policymaking. And my reference to it as an arena may turn out to have more significance than most of us would like to recognize. I do not mean to imply that the science community is about to

be locked in mortal combat with any segment of society. But it is obvious that the days when the scientific community, or certain segments of it, could stand aloof from the mainstream of social and political activity are over. Science may still be esteemed—and it is now, according to recent opinion polls. But we know that it is no longer sacred. We have been known to make mistakes. We have publicly expressed uncertainties and doubts about the extent of our knowledge. We have even argued among ourselves in public. This is not necessarily bad, but it has shown us to be mortal, and as such we become as accountable—and vulnerable—as any segment of society.

If, as a result of all this, recent years have seen the beginnings of a change in the public and governmental attitidue toward science and technology, the coming years will probably see the solidifying and institutionalizing of some very different relationships between science and society. And much of that will be reflected in national science policy and the relations between the science community and government on all levels and in all its trappings. There have been many who have recognized the seeds of this in the growing science-related activities in government and the science involvement of Congress—from the enactment of the National Environmental Policy Act (NEPA) to the current deliberations and debates on energy, resources, and the social sciences. But all this was, and is, just beginnning. As these deliberations and the debates grow, as all the subtle and not so subtle relationships between scientific advances and their effects on society become more apparent, we will most likely see an even greater involvement of the science community in the affairs of state and of the world.

Now I come to the crux of the matter. If in the context of what is happening today and its dynamics we are to ask Whither NSF?—or more broadly, to question how science itself will fare over the next 5, 10, or 25 years—the answer depends largely on the response of the science community. Certain patterns have been set that should affect the growth and direction of science over this period. We know for example what demands energy R&D will make on us during this time. Studies by the Academy and the Food and Agriculture Organization (FAO) have indicated many of the advances necessary to alleviate the world food situation. Similarly, we are getting a better picture of the challenges involved in meeting our material needs. And in recent years many criteria for a healthier environment have been set, and some measures instituted toward achieving them. But the country has yet to face fully many of the difficult questions involving the trade-offs between economic and environmental matters. Granted that scientific and engineering advances can eventually improve this situation with some technological fixes at added costs, much of the solution of this dilemma

rests on the attainment of further knowledge and on the value judgments of society, a subject about which I'll have more to say in a moment.

Of all the problem areas that are setting the pattern for scientific research in the years ahead, perhaps the most difficult may be that which we on the National Science Board have categorized in our 1975 report under the heading of the "Challenges of Society." As we stated in the report: "The challenges in this category are almost limitless," and we cited a few—including international strife, discrimination, crime and delinquency, and the spectrum of interpersonal and intergroup conflicts. The report goes on to discuss some of the obstacles to understanding and meeting these challenges. Among the important conclusions that the Board reached concerning this matter were the following, and I quote them because I concur so strongly:

> The tasks which these problems pose for science are immense. Although they involve the whole of science, the tasks apply particularly to the least developed of the disciplines—the behavioral and social sciences. These disciplines need to be significantly strengthened, in both their basic and applied aspects, if the Nation is to respond more successfully to its social problems. Although knowledge alone does not guarantee success, its lack almost certainly reduces the chance and extent of progress.

I believe this is a very important message that the science community should help convey to the American public and its representatives in the government.

Related to the subject of man's understanding of man and his society is another issue that will have a profound bearing on the future of science, and that is the matter of ethics and human values. The influences and the pursuits of science and technology have been drawn into an even closer relationship with the ethical decisions and value judgments of the society in which they operate. Over the 25 years that NSF has grown, certain developments in science have made it clear that the science community cannot conduct its affairs as a pure search for truth apart from serious considerations of its human consequences. This was not quite so apparent back in 1950 when the then President of the American Association for the Advancement of Science stated publicly: "Science cannot stop while ethics catches up—and nobody should expect scientists to do all the thinking for the country."[1] There may be some who feel that statement still has some elements of truth in

[1] Elvis Stakman, University of Minnesota, speaking as President of AAAS, January 9, 1950.

it, but the prevailing situation in science today is much closer to the one described in the current issue of *Fortune* magazine, which comments:

The world of science is searching its soul for a code of ethics and a scale of human values to govern its new professional responsibilities."

I will not go into detail on this search. Much has been written recently, and many of you may have been personally involved in the deliberations and decisions related to the ethical aspects of biological and behavioral research. Ethical and human value issues are surfacing with increasing frequency and are related to growing consequences in a number of scientific and technological areas. The time has come, and perhaps has long passed, when we can move into research and development—particularly development—of major new technologies without the fullest disclosure and public debate as to their possible social and human consequences. We may have to make a most substantial commitment of our best people to examining these issues. Dealing with this situation is already proving to be a painful process involving all the difficulties of fostering public understanding, of settling conflicts of interest, and of becoming enmeshed in adversary proceedings characteristic of our democratic society. But we in the science community have a choice of demonstrating leadership in this area or waiting until we are drawn in later, perhaps at times when issues have been clouded by misinformation and prejudicial thinking. I am not claiming that scientists should attempt to assume an elitist position in trying to influence people about their future. And "nobody *should* expect scientists to do all the thinking for the country." But I believe we will be expected—and we are obligated—to do much more than we have in the past. How successful we are at it will have much to do with the public support of science and the answer to Whither NSF?

One further word on the relation of ethics and human values to science. This is an area in which we need to have far better knowledge. We need better understanding of how values are established and the counter-influences between them and science and technology. At NSF we are supporting a program of research on this subject.

In the world today, where the application of scientific advances can have such a strong and pervasive impact, the belief is often advanced that we should first establish our values and goals and set these as the ends toward which we use our science and technology. But as much as science and technology should operate within a framework of human values, there exists the possiblity that advances in human knowledge will alter those values. For example, it is possible that the environmental movement in this country has influenced the lives of a limited number of people to the extent that they have formed a type of "back-to-the-earth" movement in their lifestyle. On a global scale, there is also con-

siderable interest in what has become known as "alternative" or "intermediate technologies", the use of small-scale, more labor-intensive and less-capital-intensive technologies to support a satisfactory type of development and living in certain parts of the world. No doubt the values that led to these choices were influenced somewhat by the state of our scientific knowledge and our technological capability, as well as previously held values. But what would have been the values of these people and how would they have been expressed had we by now fully developed systems of biological pest control, fertilization and irrigation that posed none of today's pollution, power, or water problems, a virtually limitless supply of clean, cheap energy via solar or fusion technologies, and any other technologies that would negate most of today's environmental problems?

I am not arguing here for ethical relativism but only making the point that advancing human knowledge has a strong interplay with human expectations and values, one that should be explored more fully.

On the subject of advancing knowledge, much has already been made during this symposium of the concept of "Science—the Endless Frontier." Let me conclude with a brief comment on our pursuit of that frontier. Never has it been clearer that the realm of science is something like an expanding universe growing even as our capacity and curiosity to explore and understand it grows. The intellectual challenge in understanding nature is as great or greater than it has ever been. But it is also important now for the science community to highlight the point—one that is being increasingly made today—that basic research supplies the knowledge capital that is the underpinning of our entire structure of applied science and technology. In addition, we should recognize that the administrative arrangements of science support in the years ahead—whether the NSF retains the central role in basic research support, whether more basic research is supported by the mission agencies, or whether there is eventually the creation of any other science support mechanism—are far less important to the health of science and the Nation than the calibre of people we have in science and at the helm of our science-related activities. We need the best people possible in science for the Nation to maintain the excellence of its research capability. It is only through this capability, and through its constant upgrading, that we are going to see ourselves through the complex web of problems that constitute today's and tomorrow's crises.

In the coming years, I believe that a good portion of our research capability will continue to be centered in the Nation's colleges and universities, provided they can solve their institutional problems. However, there may be much important work done in national laboratories and industrial research centers. Possibly we will see closer

and more productive ties between the universities and these other research establishments. Ways should be, and I believe will be, found to stimulate a better flow of scientific and engineering knowledge and talent between these segments of the R&D community.

If in my comments today I have not answered the question of where the NSF will be during its second quarter century, I hope I have at least indicated some of the directions in which it may go. The Foundation was born to serve the Nation through advancing the progress of science. I believe it has done this during its youthful 25 years of existence. But that period has also been a learning period for the Foundation and for many of us who have grown and learned with it. Now it's time to move ahead to even more productive days. For, as Oliver Wendell Holmes said, "The greater thing in this world is not where we stand but in what direction we are going."

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